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EFFECT OF A LATE SPRING FROST UPON FOREST VEGETATION IN THE WASATCH MOUNTAINS OF UTAH

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The dearth of concrete information on the relative frost hardiness of North American forest trees, as voiced by Phillips (4), remains practically unchanged twelve years after the publication of his paper. Authentic records of frost injury to various species would furnish an excellent scientific basis for determining the relative hardiness of different species in a given locality and of the same species on different sites. In certain cases the relative frost hardiness may prove to be the determining factor in forest succession.

Zon (6) has shown that late spring frosts are more dangerous to vegetation than those of early fall. They frequently kill the tender succulent young growth when the air temperature is 2 to 4° F. above the freezing point; and temperatures of as much as 4 to 7° F. above the freezing point, while trees are in blossom, are reported to cause poor seed years.

Studies of the biophysics and biochemistry of frost action (3) have shown that true frost injury, accompanied by ice formation within the tissues, results in plasmolysis, desiccation, precipitation of the proteins, the accumulation of sugars, and consequently a greater density of the cell sap as determined by the depression of the freezing point, and causes changes in the hydrogen-ion and salt concentrations of the juices of injured parts. The premature fall of the leaves is believed by Zon (6) to result in certain chemical changes in the xylem. With the sudden fall of the leaves, mineral salts are carried to the soil which otherwise would be stored in the wood of the tree trunk.

Because of the dearth of published information relative to frost injury to most of the species of the forest vegetation of the Wasatch Mountains notes were compiled on an especially severe frost which occurred the last of May, 1919, throughout the Intermountain region. Following a period of approximately four weeks of exceptionally warm weather a cold wave, accompanied by rain, hail and snow, resulted in very great damage in the mountainous portions of Utah at elevations above 5,000 feet. Temperatures were unusually high during practically the entire month, which was the warmest May for 18 years (1). The mean departure from the normal for 43 stations in Utah having records for 10 years or more, was 4.5° F. above the mean temperature. The highest temperatures in most cases occurred on the 27th and 28th of May, and were followed on the 30th and 31st by unusually cold weather.

At the Cottonwood Nursery, located 25 miles southeast of Salt Lake City, at an elevation of 7,400 feet on the Wasatch National Forest, serious damage was observed on most of the native and exotic trees in the forest nursery and on practically all of the native vegetation on the adjacent mountains. The preceding period of exceptionally warm weather, during which the mean temperature was approximately 5.3° F. above the average, and a maximum temperature of 78° F. was reached, resulted in the very rapid growth of the vegetation and made it succulent. All growth was far advanced on account of the season being from two to three weeks earlier than normal. During the evening of May 30 snow fell to a depth of five inches, with the relative humidity high and a temperature of approximately 32° F. Later in the night a minimum temperature of 15° F. was reached. The snow remained on the nursery grounds until the middle of the next forenoon, while on the adjacent north slopes it did not disappear until late the following day, June 1.

A careful examination was made of all stock in the nursery and of the native vegetation on the adjacent mountains. The character and extent of the frost injury will be considered in the following paragraphs.

In the nursery it was found that in general the pines were uninjured, while the spruce and fir which had made any appreciable growth during the current season were frozen in varying degrees.

Engelmann spruce, *Picea Engelmanni,* four years old (three year seedlings—one year transplants),[1] the buds of which had just opened, had practically all of the terminals and many of the laterals of the current season's growth killed. A few trees were killed to the ground, others had a portion of last season's growth killed. Those beds which were protected with a heavy cover of timothy hay three to four inches thick had very few laterals killed and only about 30 percent of the terminals frozen. Three year old Engelmann spruce seedlings which were growing compactly in beds were injured only along the edges of the bed and in thin patches. Stock grown from seed collected on the Gunnison National Forest in Colorado had not over 10 percent of the terminals frozen, while seed collected on the Wasatch National Forest in the vicinity of the nursery suffered rather severely, having approximately 50 percent of the terminals frozen.[2] Two-year-old Engelmann spruce seedlings showed very severe injury along the edges of the beds where the plants were well budded out. The injury was not so serious in the center of the bed where growth was not so far advanced. Under a covering of hay very little injury was noted; a covering of canvas proved less effective. One-year-old stock of the same species, unprotected, was not injured any more than that protected by canvas spread over the frames. Newly transplanted three-year-old Engelmann spruce seedlings had possibly 12 percent of the terminals of the taller trees killed. The process of transplanting appeared to retard the opening of the buds long enough to prevent the stock from being seriously injured. Engelmann spruce two years in the seed bed and three years in the transplant bed, which had been grown from local seed, had a large percentage of the terminals killed, but not all. This stock was, however, in a somewhat better condition than that which had been three years in the seed bed and one year in the transplant bed. Some of the laterals near the top were not killed.

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[1] [The length of time in the seed bed and in the transparent bed have an important bearing on the size and vigor of nursery stock, and is therefore given in each case.—Ed.]

[2] [This appears to be an interesting case of adaptation. Tourney in his "Seeding and Planting in the Practice of Forestry," Wiley, N. Y., 1916, gives on pp 92–95 examples of the inheritance of modifications due to the environment.—Ed.]

Two-year-old blue spruce, *Picea Parryana*, seedlings were practically uninjured except for a few along the edges of the bed. Of the four-year-old blue spruce two years in the seed bed and two years transplanted, approximately 10 percent of the taller terminals were killed. It is very probable that the covering of snow protected the majority of the tops, and that those which were killed were too near the surface of the snow. The smaller stock appeared to be better protected by the blanket of snow and the heat of the soil, since the soil was scarcely frozen under the snow.

Four-year-old Douglas fir, *Pseudotsuga taxifolia,* two years in the seed bed and two years transplanted, under a very light covering of timothy hay less than two inches thick, was rather severely frozen. Uncovered beds of the same species were so seriously injured as to render them practically worthless. Two-year seedlings one year transplated, and three-year seedlings one year transplanted, of Douglas fir covered with hay had only about 25 percent of the terminals killed, while those not covered were almost completely killed, even to a large portion of the older growth. This stock was rendered practically worthless for field planting.

Western yellow pine, *Pinus ponderosa,* was in all cases uninjured, and all lodgepole pine, *Pinus contorta,* forming a part of the contemplated output of the nursery was injured only to a very slight extent. Two-year-old lodgepole pine seedlings with 2 inches of new growth, were practically uninjured. Three-year-old seedlings of the same species, which had previously been abandoned as a part of the contemplated output of the nursery, occurring in a rather sparse stand, had approximately 25 percent of the leaders killed. From three to five inches of new and very succulent growth had occurred, the greater part of which was frozen. In an adjoining dense stand of the same age-class the only injury noted was to exceptionally tall seedlings along the edges of the beds.

Five-year-old western white pine, *Pinus monticola* (three years in the seed beds, twice transplanted) which had recently been transplanted again suffered slightly, possibly 10 percent being injured. Norway spruce recently transplanted was uninjured.

Native blue spruce about three feet tall, grown in the nursery and later transplanted on the nursery grounds, was badly frozen. In fact, only a few live branches were observed near the ground.

Norway spruce, *Picea excelsa,* four feet tall, planted in the same situation, was not so badly injured as the blue spruce. Many of the Norway spruces are budding out again. Some of them did not even have the terminals frozen.

Douglas fir, six feet tall, planted near the nursery, had all of last year's leaders killed and the tips of the branches on the lower part of the tree partially killed.

In general, the edges of all the nursery beds showed the most serious injury and the centers the least. In the centers the plants are much denser and the beginning of growth in the spring is somewhat retarded. Along the edges of the beds near the paths, and in the sparser stands, there is more of an opportunity for the sun's rays to be reflected from the soil surface. This causes sufficiently high temperatures, not only to start growth earlier, but to ordinarily prevent more serious injury from freezing.

Of the native conifers, the firs—Douglas fir, alpine fir, *Abies lasiocarpa,* and white fir, *Abies concolor*—were injured to a greater extent than the spruces. Only an occasional spruce was seen which showed any apparent injury. In a few cases branches of the latter, hanging over a small stream, were seen to have last season's leaves killed. On a northwest slope at an elevation of 7,800 feet, however, Engelmann spruce was found to be injured more seriously than the firs. This particular site was exposed to the direct effects of the storm which came from the northwest. Engelmann spruce is here near the lower limits of its range while alpine fir and Douglas fir are almost at their optimum elevation. A considerable number of alpine fir and Douglas fir seedlings and saplings were completely killed by the frost. Alpine fir as large as 18 inches in diameter breasthigh, and 65 feet tall, was also killed outright.

It is noteworthy that in the nursery the pines, although growing beside the firs and spruces, begin growth much earlier. Where spruces and firs were found growing side by side in the forest the firs had, in most cases, begun growth earlier than the spruces, which probably accounted for the smaller amount of injury to the spruces, except on the northwest slope.

Northern exposures are usually less susceptible to frost injury than southern, southwestern, southeastern, and eastern exposures because vegetative activity begins later, when the greatest danger from frost has passed. However, in this case the new growth was sufficiently advanced on the northwest exposures to show very serious damage as a result of receiving the direct action of the storm. The greatest amount of injury was observed at elevations of from 7,000 to 8,000 feet, largely because at these levels more trees had started growth than near the upper altitudinal limit of the frost action, which extended to about 9,500 feet. Although frost injury to hardwoods was observed as low as 4,200 feet, it was not nearly as serious as at higher elevations because the temperature did not drop below 30° F.

As was also observed by Eberley (2) in eastern Nebraska, the deciduous forest trees or hardwoods were injured more severely than the conifers. The buds on most of the aspen had opened and in many instances leaves one to two inches in diameter had already been formed. The aspen in many cases had not only all of the leaves of the current growth, but also much of last year's growth killed outright. In most instances all of the buds on the one-year-old branches had been killed. In a very short time the aspen trees appeared as bare as in mid-winter. For several weeks after the frost there were no signs of development, the defoliation being so complete that a cursory examination of the trees gave the impression that they had been killed outright—a similar condition has been reported by Von Schrenk (5) for sycamore in Missouri. By the end of June a number of dormant buds

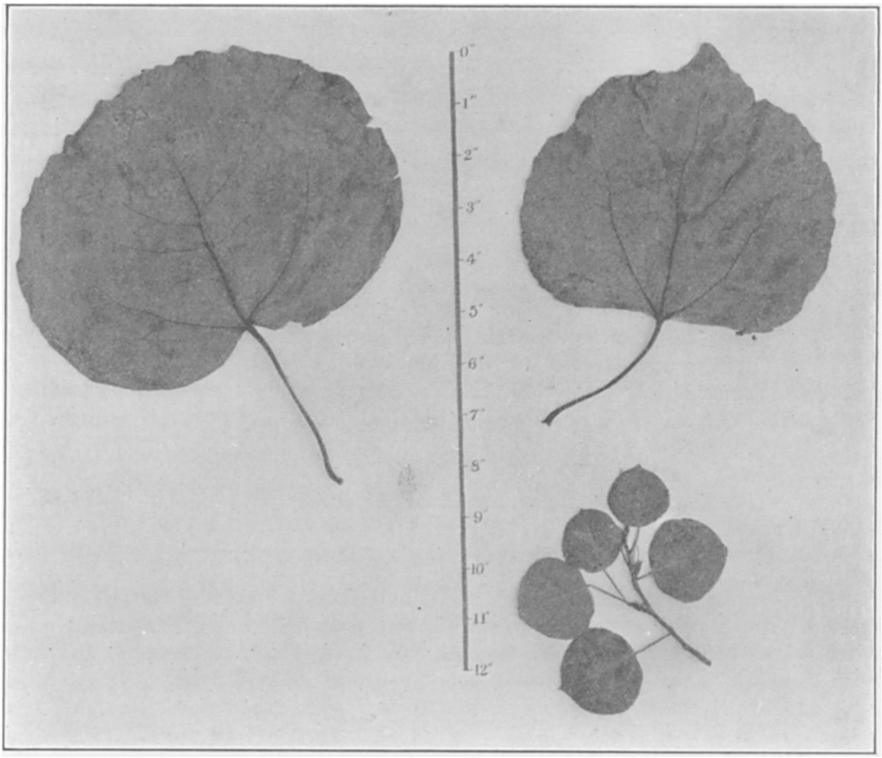

FIG. 1. Effect of frost on leaf size of aspen, *Populus tremuloides*. The two large leaves (note the inch scale) were produced after the heavy frost of May 31, 1919; the leaves on the twig in lower right hand corner are of normal size.

on the growth of the previous year which had not been killed, and newly formed adventitious buds began to develop, resulting in a partial leafing out again later in the season. The full vigor of the tree appeared to go into the relatively few shoots and new leaves, producing immense specimens; some leaves measured as much as 8½ × 10 inches, a large number exceeding 6 inches in width. Average specimens are shown in Figure 1. In most cases, the new shoots were pendant, probably because of the retarded lignification and the extra weight of the large leaves.

Box elder, alder, mountain ash, maple, Gambel oak,[3] and elder were frozen very seriously, and in the majority of cases observed the previous season's growth was killed in addition to that of the current spring. *Symphoricarpos oreophilus, Ceanothus velutinus, Ribes viscosissimum,* and *Prunus melanocarpa* were only partially frozen, and it was rather rare to find more than the current growth killed. *Pachystima myrsinites* was the only shrub that was found uninjured.

Practically all of the herbaceous vegetation was frozen to the ground. The perennial plants sprouted up again but with a less luxuriant growth containing less nutriment. The killing frost, followed by a dry period during the early summer, resulted in a material decrease in the amount of forage produced on the forest ranges and also caused it to dry up earlier than usual.

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[3] The relative frost hardiness of aspen and Gambel oak was clearly shown in Ephraim Canyon on the Manti National Forest, at an elevation of 7,800 feet. Here aspen, in marked contrast to the Gambel oak, showed no injury, while the latter suffered seriously, the elevation being near its upper limit. No injury to aspen was noted until an elevation of 8,500 feet was reached when the tops of the tallest trees showed indications of frost damage. Of all the vegetation on the Uinta National Forest Gambel oak appeared the most susceptible, the greatest damage occurring between elevations of 7,000 to 7,600 feet.